

PATENT

FLEXIBLE STRUCTURAL RESTRAINT LAYER FOR USE WITH AN  
INFLATABLE MODULAR STRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a flexible structural restraint layer for use with an inflatable module structure. The inflatable module structure has a rigid structural core and utilizes a flexible inflatable bladder. The flexible structural restraint layer works in conjunction with the bladder. In practice, the flexibility of the restraint layer is derived from utilizing flexible straps. The restraint layer surrounds the bladder and the restraint layer functions as a structure that distributes substantially the load from the bladder when the bladder is fully inflated. Loads are distributed from the restraint layer to the rigid structural core. In this way, the bladder experiences less stress when fully inflated.

1    2.    Description of the Prior Art

2           Inflatable modular structures are well known in the  
3 art.    For example, U.S. patent No. 6,439,058 to Taylor  
4 illustrates a module with a flexible shell and a bladder  
5 for inflation when deployed in space.    While various  
6 aspects of the shell are identified, i.e. debris shield and  
7 bladder, no claim is drawn to a flexible restraint layer.  
8 Further, while the patent makes reference to a flexible  
9 restraint comprised of a weave of straps as part of the  
10 TransHab concept derived by NASA, none of the claims are  
11 drawn to this invention and no specific details are  
12 illustrative of this concept.

13          U.S. patent No. 6,231,010 to Schneider, et al, also  
14 addresses an inflatable modular structure.    The Schneider  
15 invention does make reference to a structural restraint  
16 layer and claims a structural restraint as part of the  
17 module invention.    However, there are no claims exclusively  
18 to the restraint layer and no mention is made as to the use  
19 of straps as part of the structural restraint layer.

20          U.S. patent No. 6,547,189 to Raboin, et al, identifies  
21 a structural restraint layer comprised of straps as part of  
22 an inflatable module.    The restraint layer identified is  
23 drawn only to a weave of straps.    Further, there are no  
24 claims drawn specifically to just the restraint layer.    The  
25 woven strap restraint layer is identified as part of the  
26 module as a whole.

27          The drawback of the Raboin invention lies within the  
28 use of a weave of straps.    Typically, the most efficient  
29 distribution of a load using a strap is where the load is  
30 applied along the length of the strap.    As a strap is  
31 twisted or coiled, a portion of the load is directed away  
32 from the length of the strap.    In this situation a load

1 would be applied in an area that may not be specifically  
2 engineered to handle the load. This creates stress points  
3 along the strap where the strap is bent and that can lead  
4 to a failure of the strap. In a weave of straps, each  
5 strap is bent in numerous locations to conform to other  
6 straps in the weave. These bends can increase the  
7 possibility of failures.

8 A further drawback with the use of a weave is the  
9 amount of weight resulting from the number of straps being  
10 employed. In the weave are a large number of longitudinal  
11 strap (also referred to as an axial strap) to weave with  
12 the hoop straps. This is effectively a double layer of  
13 straps. As launch costs presently can be of the order of  
14 \$10,000.00 per pound, this increased weight has an adverse  
15 fiscal impact.

16 Thus, the present invention has the distinct  
17 advantages of reducing the potential stress points on a  
18 strap and results in an assembly that has less weight and  
19 thereby reduces the cost to place a module in orbit.

#### 20 BRIEF SUMMARY OF THE INVENTION

21 A flexible structural restraint layer for use with an  
22 inflatable module structure is claimed. The inflatable  
23 modular structure has a fore and aft assembly attached to a  
24 longeron and an inflatable bladder attached to the fore and  
25 aft assembly. The invention comprises a first and second  
26 circumferential strap assemblies and a radial strap  
27 assembly having opposing distal ends. The first and second  
28 circumferential strap assemblies are disposed on, and  
29 attachedly fastened to, the opposing distal ends of the  
30 radial strap assembly. There are a plurality of axial  
31 straps having opposing ends forming loops and the first and  
32 second circumferential strap assemblies and the radial

1 strap assembly have guides to receive the axial straps.  
2 The axial straps are placed through the guides and the  
3 flexible structural restrain layer is placed over the  
4 bladder. The fore and aft assemblies receive the loops of  
5 the radial straps such that the flexible restraint layer is  
6 fixedly attached to the inflatable modular structure. When  
7 the bladder is inflated, the flexible structural restraint  
8 layer distributes the load from the inflated bladder.

9 The present invention may be best understood by  
10 reference to the following description taken in conjunction  
11 with the accompanying drawings.

#### 12 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

13 Fig. 1 is a top view of a Twill Weave;

14 Fig. 2 is a partial cut-away longitudinal view of a  
15 Twill Weave;

16 Fig. 3 is a partial cut-away lateral view of a Twill  
17 Weave;

18 Fig. 4 is a top view of a Plain Weave;

19 Fig. 5 is a partial cut-away longitudinal view of a  
20 Plain Weave;

21 Fig. 6 is a partial cut-away lateral view of a Plain  
22 Weave;

23 Fig. 7 is a top view of a strap;

24 Fig. 7a is a top view of stitching on a strap securing  
25 two loops;

26 Fig. 7b is a side view of a strap having a loop at  
27 both ends;

28 Fig. 8 is an isometric view of a radial strap  
29 assembly;

30 Fig. 9 is a top view of two straps illustrating the  
31 stitching between the straps;

32 Fig. 10 is a top view of a zipper assembly;

1        Fig. 11 is an isometric view of a circumferential  
2 strap assembly;

3        Fig. 12 is a top view of a guide with a radial strap;

4        Fig. 13 is an isometric view of the assembled flexible  
5 restraint layer;

6        Fig. 14 is cross-sectional view of a zipper assembly  
7 sewn to a pair of straps; and

8        Fig. 15 is a cross-sectional isometric view of the  
9 flexible restraint layer assembled with the bladder and the  
10 rigid structural core.

#### 11 DETAILED DESCRIPTION OF THE INVENTION

12        The present invention may best be understood by  
13 reference to the following description taken in conjunction  
14 with the accompanying drawings. Fig. 1 is a top view of a  
15 segment of a Twill Weave. The Twill Weave is the weave for  
16 the preferred embodiment and is used to construct the  
17 straps.

18        Typically, a weave has a warp 100 (vertical) and weft  
19 (horizontal) 102 grouping of threads. In practice, the  
20 warp and weft threads are tightly interlaced with little,  
21 if any, space between the adjoining threads. It is this  
22 tight interlacing of threads that that results in a strong  
23 and durable fabric. This interlacing is typified in Fig.  
24 2, which illustrates longitudinal cross-section of the  
25 Twill weave, and Fig. 3, which depicts the lateral cross  
26 section of the Twill Weave.

27        The threads are comprised of a lightweight, high  
28 strength, and low elongation material. In the preferred  
29 embodiment, the threads are made of Vectran. Other  
30 suitable high strength polymer materials that may be  
31 utilized include Kevlar.

1 While the Twill Weave of Fig. 1 is preferred, the  
2 weave is not restricted to just a Twill. Other weaves may  
3 be used as the application dictates. Fig. 4 illustrates a  
4 Plain Weave pattern. Fig. 5 is a cross-section of the  
5 longitudinal weave and Fig. 6 is a lateral cross section.  
6 It is readily apparent that the pattern of the Twill Weave  
7 in Figs. 1, 2, and 3 is different from that of the Plain  
8 Weave of Figs. 4, 5, and 6.

9 There are also patterns not depicted by the figures  
10 that are well known in the art such as the Hollander Weave,  
11 the Hollander Twill Weave, and the Reverse Hollander Weave.  
12 Any of these weaves, or combination of weaves, may be used.  
13 Also, weave patterns not identified above may be employed  
14 as needed.

15 Furthermore, a chosen weave pattern may be used  
16 repeatedly to form a single strap. For example, the Twill  
17 Weave of Fig. 1 is simplified for purposes of illustration  
18 and in practice this weave may be several layers thick and  
19 much wider than depicted. Also, the warp 100 and weft 102  
20 threads may actually be a group of threads as opposed to a  
21 singular thread as depicted in the figures.

22 Turning now to Fig. 7, a strap 106 is shown having  
23 opposing ends 108 and opposing edges 110. Fig. 7a  
24 illustrates a strap 106 having two loops 112 and the  
25 stitching 113 securing the end of the strap 108 to the  
26 strap 116. The stitching pattern for securing the loops is  
27 not limited to a particular pattern, but in the preferred  
28 embodiment, the pattern is a Bartack type stitch that is  
29 well known in the field. Fig. 7b shows a side view of a  
30 strap having a loop 112 at both ends. The loops of Figs.  
31 7a and 7b are formed by folding the end of a strap back  
32 onto the strap and stitching substantially the end of the

1 strap with the strap. This is in fact the preferred  
2 embodiment. Straps with and without loops as depicted in  
3 Figs. 7, 7a, and 7b will be referred to repeatedly  
4 throughout this detailed description.

5 A radial strap assembly 114 is shown in Fig. 8  
6 comprising a plurality of individual straps. In this  
7 application, the straps are elongated radial straps 116.  
8 Each elongated radial strap 116 is laid edge to edge and  
9 fixedly attached together by stitching.

10 The stitching attachment between straps is further  
11 identified in Fig. 9. The edges 110 of adjoining straps  
12 are brought together and a stitch 118 is used to secure the  
13 edges together. The figure depicts a distance between the  
14 opposing edges 110 for purposes of illustration only. In  
15 application, the edges 110 are brought together. Further,  
16 the type of stitching pattern utilized will be dependent  
17 upon the application. When the straps are laid side-b-  
18 side, or edge-to-edge, or adjacent to one another, then  
19 they are said to be abutting one another. In the preferred  
20 embodiment, the stitching pattern is a zig-zag pattern.  
21 However, other stitch patterns may be used as dictated by  
22 the specific situation.

23 Returning now to Fig. 8, the figure portrays a window  
24 opening 120 in the radial strap assembly 114. At least one  
25 window opening is present in the preferred embodiment.  
26 However, alternate embodiments can have multiple window  
27 openings or none at all.

28 The elongated radial straps 116 on both sides of the  
29 window opening 120 have the opposing ends 108 stitched  
30 together. In the proximity of the window opening 120, the  
31 elongated radial straps 116 have a loop 112 for attaching  
32 to a window assembly. In this case, the opposing end 108

1 of the elongated radial strap 116 is stitched to the  
2 opposing end 108 of another elongated radial strap 116 also  
3 having a loop 112. In another embodiment, each strap on  
4 both sides of the window opening can be a single strap with  
5 a loop at both ends, rather than two straps stitched  
6 together. In practice, the window opening would be through  
7 the bladder of an inflatable modular structure and would  
8 work with a window assembly.

9 Referring now to Fig. 10, a zipper fastener 124 is  
10 illustrated. This is a typical zipper assembly having  
11 opposing tapes 126, a pull tab 128, teeth 130 on each  
12 opposing tape 126, a box, 132, a pin, 134, and a top stop  
13 136.

14 Returning now to Fig. 8, the opposing distal ends 122  
15 of the radial assembly 114 are sewn to a tape 126 of a  
16 zipper fastener as typified in Fig. 10.

17 Addressing Fig. 11, the circumferential strap assembly  
18 138 is shown. There are two such assemblies, a first and  
19 second circumferential strap assemblies, and one assembly  
20 fits to each end of the radial strap assembly discussed  
21 above. The straps used in the circumferential strap  
22 assembly have opposing ends as identified in Fig. 7 and are  
23 referred to here as elongated circumferential straps 140.  
24 Each circumferential strap 140 has a different length from  
25 the other straps. This is due to the fact that the  
26 circumferential straps 140 are positioned to form  
27 substantially a half sphere when laid edge to edge.

28 Again, as in the case of the radial strap assembly,  
29 the circumferential straps are laid edge-to-edge and  
30 stitched together. Along the edge of the longest strap 142  
31 the opposing mating tape 126 of Fig. 10 is sewn into place.



1 This allows the circumferential strap assembly to fasten to  
2 the radial strap assembly by way of the zipper fastener.

3 Fig. 12 illustrates an axial strap 142 disposed within  
4 a guide 144. The guide is made of Vectran in the preferred  
5 embodiment and is attached to the circumferential and  
6 radial strap assemblies. The guide acts to align the axial  
7 straps. In the preferred embodiment, the guides are  
8 secured in place with stitches. The guides may take the  
9 form of a sleeve that fits over the strap. In alternate  
10 embodiments, the guide may take the form of another  
11 material that is lightweight, high strength, and exhibits  
12 low elongation. This could include materials having  
13 Kevlar. In this fashion, the axial strap 142 is kept in  
14 place without being sewn to the circumferential strap  
15 assemblies or the radial strap assembly. The axial strap  
16 142 is of the form of the strap illustrated in Fig. 7b and  
17 has loops 112 at each end.

18 To further illustrate this point, Fig. 13 shows the  
19 assembled flexible restraint layer 146. In this  
20 illustration, the guides 144 are disposed at intervals on  
21 the surface of the radial strap assembly 114 and the  
22 circumferential strap assemblies 138. The selves are 144  
23 sewn into place. The axial straps 142 fit within the  
24 guides 144. At both ends of the flexible restrain layer  
25 146 the loops 112 of the axial straps 142 extrude beyond  
26 the circumferential strap assemblies 138.

27 In the proximity of the window opening 120, the axial  
28 straps take the form of the straps identified in Fig. 7b  
29 with loops at both ends. The difference between the straps  
30 in the area of the window opening and the remaining axial  
31 straps is in the length of the straps. In regards to the  
32 window opening, the axial straps extend from the fore or

1 aft assembly to the area of the window opening. Then on  
2 the other side of the opening, another strap extends to the  
3 other assembly. The other axial straps that do not  
4 encounter the window opening extend from the fore to the  
5 aft assemblies without interruption.

6 The circumferential strap assemblies 138 are fastened  
7 to the radial strap assembly 144 by way of the zipper  
8 fastener. As illustrated, there are two circumferential  
9 strap assemblies. Again, they are referred to as the first  
10 and second circumferential strap assemblies. Fig. 10  
11 illustrates how the zipper would engage and thereby fasten  
12 the circumferential strap assemblies 138 to the radial  
13 strap assembly 144. Turning now to Fig. 14, the tape 126  
14 is sewn 146 to a strap 106. When the zipper teeth 130 are  
15 engaged, the straps 106 overlap 148. This overlap helps to  
16 insure that the bladder 150 is not pinched or cut by the  
17 zipper. In an alternate embodiment, the straps do not  
18 overlap, but rather meet side by side to protect the  
19 bladder from the zipper.

20 Addressing now Fig. 15, the flexible restraint layer  
21 146 covers the bladder 150. The restraint layer 146 and  
22 the bladder 150 are securedly fastened to the fore 152 an  
23 aft 154 assemblies while the longerons 156 separate the  
24 fore and aft assemblies. Fastening of the bladder to the  
25 fore and aft assemblies is accomplished by known means such  
26 as the use of end rings and/or attachment rings. The fore  
27 and aft assemblies and the longeron compose the rigid  
28 structural core. In the preferred embodiment, there are  
29 four longerons 156, the fore assembly 152 is an airlock  
30 that is adapted to hold the strap loops 112 securedly in  
31 place by known conventional means such as the use of  
32 rollers or a bar, and the aft assembly 154 is used

1 primarily for storage, but also has the same means for  
2 securing the strap loops 112. Also, the fore and aft  
3 assemblies are adapted to secure the bladder in place. In  
4 an alternative embodiment, the aft assembly 154 may also be  
5 an airlock. Further, in the preferred embodiment, the fore  
6 and aft assemblies are made of steel and the longerons are  
7 made of aluminum. However, this does not limit the use of  
8 other rigid structural materials.

9 When the bladder 150 is inflated, the flexible  
10 restraint layer 146 provides the outer boundary for the  
11 expansion of the bladder. The load is distributed through  
12 the restraint layer 146 to the fore 152 and aft 154  
13 assemblies and the longerons 156. In this way, the bladder  
14 does not bulge out beyond an acceptable limit.

15 There has thus been described a novel flexible  
16 restraint layer for use with an inflatable modular  
17 structure. It is important to note that many  
18 configurations can be constructed from the ideas presented.  
19 The foregoing disclosure and description of the invention  
20 is illustrative and explanatory thereof and thus, nothing  
21 in the specification should be imported to limit the scope  
22 of the claims. Also, the scope of the invention is not  
23 intended to be limited to those embodiments described and  
24 includes equivalents thereto. It would be recognized by  
25 one skilled in the art the following claims would encompass  
26 a number of embodiments of the invention disclosed and  
27 claimed herein.

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